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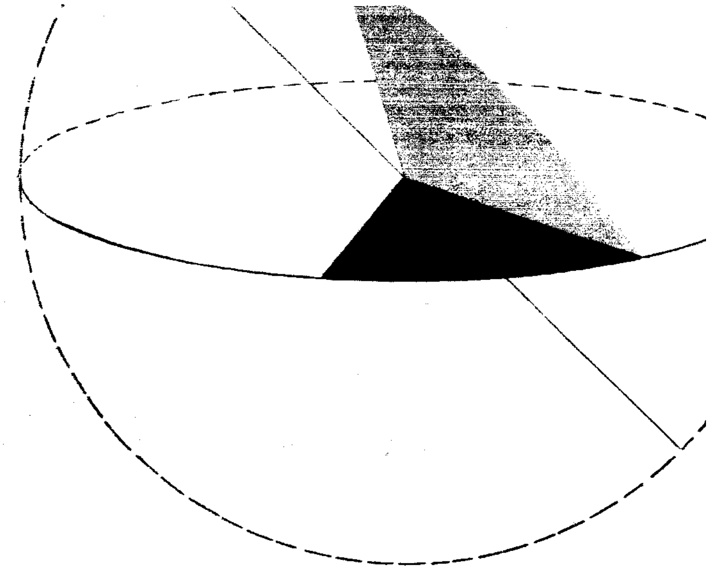

Radio Location of the Planet Venus

Izvestia, May 12, 1961

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RADIO LOCATION OF THE PLANET VENUS

per Izvestia, May 12, 1961

Translated by J. L. Zygielbaum

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA
March 6, 1962

PREFACE

This translation of two articles that appeared in Izvestia on May 12, 1961 purports to be a description of a Russian radar experiment with the planet Venus, similar in many respects to the successful U. S. experiment conducted initially on March 10, 1961, and officially released by U. S. newspapers on March 17, 1961.

A detailed description of the preparations for the U. S. experiment was reported in JPL Research Summary No. 36-7, Volume I, and the results were included in Research Summary No. 36-8, Volume I. JPL Technical Report No. 32-132 also presented the results of a successful U. S. radar exploration of Venus on March 10, 1961.

The Russian articles do not indicate the date that the Soviet experiment is supposed to have occurred.

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ABSTRACT

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The Soviet Union has recently (1961?) conducted a radio location of the planet Venus. The basic purposes of the radio location of Venus were (1) to investigate the physical properties of the planet's surface, (2) to evaluate the period of its rotation, and (3) to define more accurately the dimensions of the solar system. All three goals were purported to have been achieved. The processing of the results of the radio location of Venus is continuing. These results will be published in Soviet scientific journals. The date, however, of the above radar location of Venus was not indicated by the Russian press.

I. RADIO LOCATION OF THE PLANET VENUS

Communique of the Academy of Sciences, USSR,
per Izvestia, May 12, 1961

As reported by the Academy of Sciences, USSR, the Soviet Union has recently conducted a radio location of the planet Venus. The basic purposes of the radio location of Venus were (1) to investigate the physical properties of the planet's surface, (2) to evaluate the period of its rotation, and (3) to define more accurately the dimensions of the solar system. The radio location was conducted during the period of the inferior conjunction between Venus and Earth. The distance to Venus during the measurement period was somewhat more than 30,000,000 km and was measured frequently with high accuracy.

For the purpose of radio location, a wave in the medium decimeter range was selected. The force of current which was sent from the Earth equalled 250 mw per steradian. The visible surface of Venus has, thereby, received a power of about 15w. The transmitted signal had a circular polarization, and the reception was conducted with an antenna of a linear polarization.

The measurement results have made it possible to define more accurately the value of the astronomical unit (mean distance between the Earth and the Sun), which proved to be equal to 149,457,000 km.

An analysis of the radio signal which was reflected from the planet Venus has indicated that a widening of the frequency spectrum takes place, which is caused by the rotation of the planet. According to the magnitude of this widening, it was possible to evaluate the period of rotation of that planet around its axis, which proved to be close to 10 terrestrial days.

On the surface of Venus, regions with various coefficients of radio-wave reflection were observed.

The processing of the results of radio location of the planet Venus is continuing. The results of this processing will be published in scientific journals.

II. RADIO LOCATION OF VENUS

Academician V. A. Kotelnikov and Professor I. S. Shklovsky
per Izvestia, May 12, 1961

The Academy of Sciences, USSR, has announced today a new outstanding achievement of Soviet science. The USSR has conducted a radar observation of the planet Venus, which yielded important information about the planet, as well as the entire solar system.

The observation has made it possible to define more accurately the dimensions of the solar system and to evaluate for the first time the rotational period of Venus. Data were received indicating the presence of regions having various coefficients of radio-wave reflection.

The scientific value of these results is very great because, in spite of the fact that Venus is our closest neighbor in the solar system (disregarding some very small planets, called asteroids, which sometimes approach the Earth at much closer distances than Venus), we know very little about that planet. This fact is true even though Venus is the brightest object in the sky, next to the Sun and the Moon. The reason for such an "abnormal" situation from an astronomical standpoint is the thick layer of clouds in which this planet is wrapped. Consequently it is impossible to detect, by means of direct observation of details on the planet's surface, the rotation period of the planet around its axis. In the case of Mars, on the contrary, the surface is not covered by a thick layer of clouds, and the period of rotation is determined with extreme accuracy up to 1/1000th of a part of a second (this period by the way is very close to the Earth's period of rotation).

The question of the character of the rotation of Venus is of cardinal importance, because of the nature of this remarkable planet which is very similar to our own Earth in dimensions and mass. The fascinating question of possible life on Venus is also related very closely with this rotational problem. The problem will also be very essential for future astronauts. If, for instance, we assume that Venus completes one turn around its axis against 225 Earth turns (that is, during a period of time which it takes Venus to travel around the Sun), then Venus would always face the Sun with the same side (similar to the relation of the Moon to our Earth). In this case, the natural conditions would have been entirely different on the day and night sides of Venus. Such a condition in the rotation of Venus would have been extremely unfavorable for the development of life.

Since it is impossible by means of direct observations of details on the surface of Venus to determine the period of its rotation, astronomers have applied, at different times, various methods for the solution of this problem. For instance, the renowned Russian astrophysicist, Academician A. A. Belopolsky, made attempts between 1903 and 1911 to determine the period of rotation of Venus with a spectrascopic method. This method utilizes the following principle. Assuming that the planet rotates, then one of its rims will obviously come closer to us at a time when the other side will depart from us. It is known that the wavelength of any given spectral line of light moves either in a long wave or short wave direction, depending on the departure or approach of the light source (doppler effect). The magnitude of this displacement is very insignificant and depends only on the relative speed of the light source and the observer, along a direct line of vision between them. A. A. Belopolsky did not, however, obtain any proper indications as to the presence of systematic variations in the wavelengths of spectral lines of radiation from the rims of the disc of Venus.

In 1958, Richardson, using highly improved instruments, made attempts to determine the rotational period of Venus with the Belopolsky method.

However, the results were still negative. According to these observations, it was only possible to draw the conclusion that if Venus is rotating from west to east (that is in the same direction as the Earth), the period of its rotation exceeds 7 days; however, if Venus is rotating in the opposite direction, then the period of its rotation should be about 3.5 days.

Several years before Richardson's observations, the more experienced French astronomer, Dolfus, came to the conclusion that the period of rotation of Venus coincides with its period of rotation around the Sun; that is, it equals 225 Earth days. Several years ago the American radio astronomer, Kraus, found that on the wave of 11 m Venus propagates short duration radio impulses which are somewhat similar to impulses observed on Earth during thunder storms, but considerably more powerful. Under the assumption that the characteristic repetitions of such impulses occur at some determined region of the planet, Kraus claimed that the period of rotation of Venus is very short, only about 22 hr and 17 min. However, subsequent observations with considerably more powerful radio telescopes did not confirm the results by Kraus. There were also other attempts to determine the speed of rotation of that planet, but these did not yield any reliable results. Thus, it might be said that the period of rotation of Venus was completely unknown up to now.

This fact brings up another question: What is the direction of the axis of rotation of Venus in relation to the plane of its orbit? We will assume that the axis of rotation of Venus is perpendicular to the plane of its orbit. In that case, there would be no change in annual seasons on that planet. It is worth mentioning that the Earth's axis is inclined towards the orbital plane at an angle of 66°33', and Mars' axis at an angle of 64° 48'. For that reason a change of seasons takes place on Mars as well as on Earth.

The American astronomer, Kuiper, determined with very little reliability the inclination of the axis of Venus. Kuiper proposed that on Venus, just as on Earth, an over-all circulation of clouds takes place in a direction parallel with the equator. Then from the tendencies of the formations of these clouds, which were observed in ultraviolet rays and which covered the surface of the planet, he found along the parallel lines that the axis of rotation of Venus is inclined toward the orbital inclination on an angle of 58°. If this fact is true, then a change of annual seasons will take place on Venus. We will mention here that the Soviet astronomer, V. I. Yezersky, has also obtained indications on the presence of seasonal changes on Venus from his photometric observations.

Ideas, new in principle, for the study of Venus with the help of radio location were realized recently. In the method of radio location or radar, the investigated object is "illuminated" by radio waves from the transmitter, and then waves which are reflected from that object are received. By the length of time which it takes for a radio signal to travel from the locator to the object and back, it is possible to determine with high accuracy the distance to that object.

If the reflecting object is in motion then, due to the doppler effect, the wavelength and consequently also the frequency of the reflected oscillations will differ from the wavelength and frequencies which were sent by the locator. According to these changes, it is possible to determine if the reflecting object is coming toward us or departing from us, as well as the speed of its motion. In case the reflecting object is rotating, then various parts of this object will reflect signals with different frequencies. By such a broadening of the frequency spectrum of the reflected oscillations, it is possible to determine the speed of rotation. In addition it is also possible to determine, in principle, the character of the surface of the parts of a planet's disc which comes toward us or departs from us with varying speeds in its rotation, since these parts will yield reflections of the signal with varying frequencies.

Radar observations of the Moon were conducted in Hungary and in the U.S. immediately after World War II. In its time, these were great achievements. The location of more distant heavenly bodies was impossible at that time. The power of the radar transmitter must be increased proportionally to the fourth power of the distance to the Moon, and inversely proportional to the square of its diameter. Thus, during the transition from the location of the Moon to the location of Venus, resulting in an increase in planetary distance of approximately 100 times and an increase in planet diameter of approximately 3.5 times, it was necessary to increase by at least 5,000,000 times the power of radio-wave current which was emitted from the radio locator, thereby preserving the sensitivity of the receiving installation.

The first radar measurements of the distance to Venus during the period of its inferior conjunction were made in 1958 in the U.S., and in 1959 in England (in 1958 the U.S. did not succeed in receiving signal reflections from Venus). However, due to a very weak signal, the results obtained were not sufficiently reliable. A change in frequency of the reflected signals, because of the rotation of Venus, was not observed then with the observation instruments which were utilized.

The radio location of Venus which was conducted in the USSR has permitted us to register reliable reflections from Venus of radio waves which were sent from Earth, thanks to the powerful transmitters, huge antennas, and sensitive receiving installations.

The force of the radio waves which hit the surface of Venus during these measurements reached 15 w. This fact made it possible to measure the distance to Venus with great accuracy and reliability and to determine more precisely the dimensions of the solar system, which will be discussed later in this paper. By the variations of the frequency in the reflection of signals from Venus, it was possible to obtain information on the rotation of this planet.

It was proven that the variation in radial speeds of separate reflecting parts of the surface of Venus equalled approximately 80 m/sec. Using this information, we came to the conclusion that the period of the rotation of Venus is close to 11 days (assuming that the axis of rotation of Venus is perpendicular toward the direction of Earth-Venus and providing that all parts of the Venus surface are reflecting the signals). The rotation period will be somewhat shorter under different assumptions.

So, if we accept the inclination of the axis of Venus to be in accordance with the results by Kuiper, which were discussed above, then the period of rotation of Venus should be considered about 9 days.

The distance to the planet Venus, which was obtained with these radar methods at the moment of observations, has permitted us to perfect considerably the average distance from the Earth to the Sun (known as the "astronomical unit") or even the large semiaxis of the ellipse over which the Earth travels around the Sun. This is not an accidental name since the average distance from the Earth to the Sun is actually the scale of all cosmic distances. Thus, for instance, the distance to stars and galaxies is determined by this unit.

Until recently, astronomers have known an astronomical unit with an accuracy which was entirely sufficient for the majority of astronomical problems. However, for astronautical purposes, such an accuracy was not sufficient. What were the earlier methods for the determination of an astronomical unit? Many of these methods are very old and have been used for centuries. We will mention the fact that, in the majority of cases, the problem was reduced to the determination of a distance to any given planet. Then, by means of calculation according to well-known laws of celestial mechanics, the astronomical unit was determined.

The distance to a planet can be determined if the planet is observed simultaneously from two points on the surface of the Earth. Knowing with great accuracy the Earth's radius and the coordinates of the observation points, it is possible to determine by means of calculation the distance to the planet. This method is, in principle, identical with the method used in topography during the determination of distances to unaccessible objects; however, the accuracy of observation and calculations should be considerably higher. The best results are yielded by observing very small planets (asteroids) which are close to the Earth. The same problem can be solved if the planet is observed from one point on the Earth's surface, and also observed at least three times at various moments of time.

For the purpose of determining an astronomical unit, the very rare occasions when the planet Venus passed between the Earth and the Sun were also utilized. From two points on the Earth's surface, the moments when Venus appeared on the disc of the Sun were observed with great accuracy. Good results were obtained, for instance, back in the eighteenth and nineteenth centuries during four passages of Venus across the disc of the Sun.

There are also other methods for determining an astronomical unit. It is possible, for instance, to utilize the phenomena of light aberration. Because of this phenomena, each star describes on the sky a certain ellipse during the period of 1 year. The large axes of such ellipses are the same in the case of all stars and equal a very low value (about 40 angular seconds). The small axes of various stars differ strongly depending on the position of the stars on the sky.

From the theory of aberration, we know that the value of the large axes of the ellipses, which stars describe on the sky during a year, depends only on the speed of the Earth's motion along its orbit. Knowing the speed of this motion and the duration of the period of the Earth's rotation around the Sun (1 year), it is possible to find a fairly accurate distance from the Earth to the Sun.

We might also mention here another method which consists of an analysis of small changes in the wavelengths of lines in the spectra of stars, which have an annual periodicity. These changes are caused by the doppler effect because of the orbital movement of the Earth. Finally, there are methods which are based on a very fine analysis of peculiarities in the motion of the Moon.

All these methods agree sufficiently well on the value of an astronomical unit. The average distance from the Earth to the Sun, which was obtained with these methods, proved to be 149,500,000 km. However, the possible error in this distance might reach hundreds of thousands of kilometers.

According to the Soviet radar observations, the magnitude of an astronomical unit equals 149,457,000 km, with a possible error of less than 5,000 km.

Of course, during the determination of the distance to stars, the error in the value of an astronomical unit which was used in the old astronomical observations is completely not essential.

Other errors are incomparably more important, and an inaccuracy in the accepted value of an astronomical unit "disappears" in these cases. However, an entirely different situation appears during calculations of a trajectory for interplanetary rockets. In this case, an unreliability in the knowledge of an astronomical unit might lead to a considerable miss of a rocket in regard to a planet. Lack of reliability in the knowledge of an astronomical unit leads to the fact that the deviation of the calculated trajectory from the center of the planet might reach many tens of thousands of kilometers, which of course is intolerable.

A new, very accurate value of the astronomical unit, which was obtained with the radio-location method, improves considerably the reliability of trajectory calculations for interplanetary rockets.

The radio location of Venus, which lead to an essential perfection of the value of the astronomical unit and determined reliably for the first time the basic characteristics of the rotation of the planet Venus, is an outstanding achievement of Soviet science.